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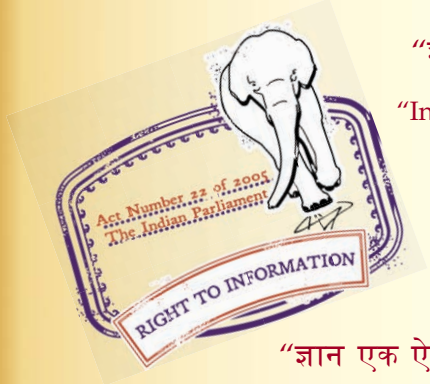
IS 14654 (1999): Minimising evaporation losses from reservoirs - Guidelines [WRD 10: Reservoirs and Lakes]



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भारतीय मानक

जलाशयों से वाष्पन क्षति कम करना — मार्गदर्शिका

Indian Standard

MINIMISING EVAPORATION LOSSES FROM RESERVOIRS — GUIDELINES

ICS 93.160

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 1999

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FOREWORD

This Indian Standard was adopted by Bureau of Indian Standards, after the draft finalized by the Reservoirs Sectional Committee, had been approved by the River Valley Division Council.

A few years ago the water resources of the country were considered to be inexhaustible and its availability was taken for granted. But, due to intensive agricultural practice, increase in population, rapid industrialization, urbanisation, etc, scarcity of water is now being increasingly felt in many parts of the country. It is not uncommon these days to transport water over long distances by train or other mechanical means. It has, therefore, become imperative that wastage of water should be controlled in all usages and every effort should be made to conserve water.

It is an established fact that huge quantity of water is lost annually from reservoirs and other water bodies by way of evaporation. Substantial quantity of water could be conserved by control of evaporation. This Indian Standard gives guidelines about various methods available for evaporation control including control of evaporation by chemical method.

Available information on laboratory and field experiments conducted by various agencies for evaporation control has been taken into account while formulating this standard.

Indian Standard

MINIMISING EVAPORATION LOSSES FROM RESERVOIRS — GUIDELINES

1 SCOPE

This standard stipulates guidelines for reduction of evaporation losses from water bodies, with special reference to control of evaporation with chemical retardants. It also gives details of various measures available for control of evaporation.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
5235 : 1992	Raingauge, recording
5681 : 1992	General meteorological thermometers, liquid in glass (*second revision*)
5793 : 1970	Aneroid barometers
5798 : 1970	Mercury barometers
5799 : 1970	Windvane
5948 : 1970	Thermometer screens
5973 : 1970	Pan evaporimeter
6939 : 1992	Method for determination of evaporation from reservoirs (*first revision*)
7243 : 1974	Sunshine recorder

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Collapse Pressure

The lowest pressure at which the monolayer collapses.

3.2 Equilibrium Spreading Pressure

The surface pressure of a mono-molecular film which exists when a solid or drop of the material is in equilibrium with a monolayer.

Explanation — Monolayer and mono-molecular film are the same. Molecules of chemicals like hexadocosanol show a unique property when in contact with water. The molecules stand on ends like bristles of brush with one end attracted to water and other end repelled by it. If the chemical is in sufficient quantity, the molecules spread on water surface and join tightly with each other forming a layer called monolayer or mono-molecular film.

3.3 Evaporation

The process by which water is changed from the liquid state into the gaseous state below the boiling point through the transfer of heat and wind energy.

3.4 Evaporation Retardants or Evapo-Retardants

Chemicals capable of forming a thin mono-molecular film on the water surface which reflects energy inputs from atmosphere and thus reducing evaporation.

3.5 Film Pressure

The difference between the surface tension of water and the surface tension of water covered with a monolayer.

3.6 Indicator Oil

A solution of light mineral oil or other suitable oil used for field identification of monolayer.

3.7 Self-Sealing Monolayer

Monolayer having the property of re-sealing itself on being ruptured or broken by wind boats, raindrops, etc.

3.8 Surface Tension

A phenomenon peculiar to the surface of liquids in which the surface molecules seem to have a greater cohesion with one another, than the molecules in the body of the liquid, so that the surface acts like a stretched elastic film.

3.9 Wind Breakers

A barrier composed of trees, shrubs or other vegetation planted around the periphery of the reservoirs for reducing the velocity of wind over the water surface in order to retard evaporation.

4 METHODS OF EVAPORATION CONTROL

4.0 A number of factors affect the evaporation from open water surface, of which, the major factors are, the water spread area and frequent change of speed and direction of wind over the water body. Other meteorological factors like,

a) vapour pressure difference between water surface and the layer of air above;
b) temperature of water and air;
c) atmospheric pressure;
d) radiation;

e) heat storage in water body; and
f) quality of water,

have direct influence on the rate of evaporation.

Since the meteorological factors affecting evaporation cannot be controlled under normal conditions, efforts are made for inhibition of evaporation by control of flow of wind over water surface or by protection of the water surface area by physical or chemical methods. The methods generally used are as follows:

a) Wind breakers,
b) Covering the water surface,
c) Reduction of exposed water surface,
d) Integrated operation of reservoirs,and
e) Treatment with chemical water evapo-retardants (WERs).

4.1 Wind Breakers

4.1.1 Wind is one of the most important factors which affect rate of evaporation loss from water surface. The greater the movement of air over the water surface, greater is the evaporation loss. Planting of trees normal to windward direction is found to be an effective measure for checking of evaporation loss. Plants (trees, shrubs or grass) should be grown around the rim of tanks in a row or rows to act as wind breaker. These wind breakers are found to influence the temperature, atmospheric humidity, soil moisture, evaporation and transpiration of the area protected.

4.1.2 Plants to act as wind breakers are usually arranged in rows, with tallest plants in the middle and the smallest along the end rows, so that more or less conical formation is formed.

4.1.3 Trees grown as wind breakers are constantly subjected to usual stress of wind, temperature, moisture, evaporation, insects and diseases. Thus, plants selected as wind breakers should be capable of resisting these stresses. The list of vegetation recommended by Indian Council for Agricultural Research, New Delhi (Technical Bulletin No. 22) for planting as wind breakers in different regions of India is given in Annex A. The spacing between plants varies from place to place, depending upon the climate and type of the soil.

In general the following spacings are recommended :

a)	Shrubs	0.60 to 1.00 m
b)	Medium height broad leaved trees	1.50 to 2.00 m
c)	Medium to tall evergreen trees	2.10 to 2.40 m
d)	Tall broad leaved trees with conical crown	2.40 to 3.00 m

4.1.4 Spacing of plants at 3 m or more is found to have little effect in reduction of wind velocity over the protected area.

4.1.5 Wind breakers are found to be useful under limited conditions for small reservoirs. In large reservoirs, wind breakers are not effective, as their action is limited to a short distance from the rim of the reservoir, thereby exposing the inner water spread area to the hazards of wind.

This method has also the disadvantage of large quantity of water being lost due to transpiration by the trees planted. The wind breakers may, therefore, be employed in specific high wind locations. In such locations, chemical method of evapo-retardation may not be feasible as the monolayers of water evapo-retardants (WER) are found to break due to high wind velocities.

4.1.6 Use of synthetic polytrees and poly shrubs are also useful for creating barriers against the wind. This type of wind breakers can be raised in least possible time. However, the effectiveness of these synthetic plants and their economy in conservation of water is yet to be established.

4.2 Covering the Water Surface

4.2.1 Covering the surface of water bodies with fixed or floating covers considerably retards evaporation loss. These covers reflect energy inputs from atmosphere, as a result of which evaporation loss is reduced. The covers literally trap the air and prevent transfer of water vapour to outer atmosphere.

4.2.2 Fixed covers are suitable only for relatively small storages. For large storages, floating covers or mat or spheres may be useful and effective. However, for large water surfaces the cost of covering the surface with floats is prohibitive. Further in case of reservoirs with flood outlets, there is also the danger of floats being lost over spillway or through outlets. The floating covers are thus of limited utility to larger water bodies.

4.3 Reduction of Exposed Water Surface

In this method shallow portions of the reservoirs are isolated or curtailed by construction of dykes or bunds at suitable locations. Water accumulated during the monsoon season in such shallow portions is diverted or pumped to appropriate deeper pockets in summer months, so that the shallow water surface area exposed to evaporation is effectively reduced.

4.4 Integrated Operation of Reservoirs

This method is suitable for a system of reservoirs which can be operated in an integrated way. The method consists of operating the reservoirs in such a way that

total exposed water surface area is kept minimum during the depletion period. Consequently evaporation loss gets minimised. For achieving this objective water use should be planned in such a way that shallow reservoirs with large water spread area are depleted first.

4.5 Treatment with Chemical Water Evapo-retardants (WERs)

4.5.1 Chemicals capable of forming a thin mono-molecular film have been found to be effective in reducing evaporation loss from water surface. The film so formed reflects energy inputs from atmosphere, as a result of which evaporation loss is reduced. The film allows enough passage of air through it and hence, aquatic life is not affected. The film developed by using fatty alcohols of different grades is found most useful for control of evaporation. These materials form a film of mono-molecular layer when applied on water surface which works as a barrier between water body and the atmospheric conditions. These fatty alcohols used for evaporation control are generally termed as chemical water evapo-retardants (WERs) and these are available in the form of powder or emulsion.

4.5.2 These chemical water evapo-retardants have the disadvantage of high cost of application. However, when adopted in scarcity period, drought, etc, the quantity of water saved by this method would work out cheaper than alternate means of bringing water from far off places by manual or mechanical transport. The economics of WER application may however vary from site to site depending on local factors. The chemical water evapo-retardants have another limitation of the monolayer breaking at high wind velocities.

5 PROPERTIES OF CHEMICAL WATER EVAPO-RETARDANTS MONOLAYER

5.0 For evaporation control, WER used shall have the following basic properties:

a) It should spread easily and form a compact, cohesive and even mono-molecular film on water surface.

b) The thin film formed by spreading WER should be pervious to oxygen and carbon di-oxide, but tight enough to prevent escape of water molecules.

c) It should be sufficiently durable and should reseal itself, in case it is broken due to external disturbances as wind, waves, etc. The pressure of film so formed is also found to have a definite relation to the efficiency of the monolayer.

d) The chemical WER should be tasteless, odourless, non-toxic and non-inflammable. It should have no effect on quality of water and aquatic life.

e) It should not be affected by water borne bacteria, proteins and other impurities in the water.

5.1 Compounds having the above desired properties which are mainly used for evaporation retardation, are cetyl alcohol or hexadecanol ($C_{16}H_{35}OH$), stearyl alcohol or octadecanol ($C_{18}H_{37}OH$) and behenyl alcohol ($C_{22}H_{45}OH$), or a mixture of these compounds. All these alcohols should be 99 percent pure for getting the desired properties of monolayer.

5.2 Indicator Oils

5.2.1 For effective retardation of evaporation, the molecular film formed should develop adequate pressure. In most cases the initial film pressure is in the range of 20-30 dynes/cm^2 and equilibrium pressure of 40 dynes/cm^2 can be achieved with appropriate dosage. For testing the pressure of WER film, oils of known spreading pressure (indicator oils) are used. The surface pressure developed by certain indicator oils are given in Annex B.

6 GUIDELINES FOR USE OF CHEMICAL WERs

6.0 The following guidelines are suggested for using WER in arid, drought prone or water deficit areas. These are broad guidelines only and may be varied depending on the site conditions or according to the manufacturer's specification for WER and equipment used.

6.1 Application in Emulsion Form

6.1.1 The dose of emulsion per day may be 500g/hectare of open water surface for initial 15 days. It can be reduced to 250 gm/hectare in the subsequent periods of application. The required quantity of emulsion may be diluted with water 20 to 25 times by volume for ease of application. Mixing of emulsion with water may be done either manually or mechanically. The later, however, gives more homogenous mix. The diluted mix is then filtered to separate out lumps or impurities which could block the dripping line.

6.1.2 Application of the solution is done by dripping from storage drums fixed on floating rafts or on shore dispensers. A drum of 30 litres capacity may approximately cover one hectare of water surface area whereas a drum of 200 litres capacity may approximately cover an area of 7 hectare. Four drips may be provided in a 200 litres capacity drum, while two drips may be provided in a 30 litres capacity drum.

6.1.3 The floating rafts may be positioned on water surface in grids of size depending on the capacity of the drums so that the entire area of the water surface is covered. The rafts should be anchored to avoid drift. In case the site condition does not permit anchoring of floating rafts and the reservoir to be treated is comparatively small, the drums may be mounted on shore dispensers positioned along the periphery of the reservoir. Prevailing wind direction helps in spreading and building of a film.

6.1.4 Heavy wind velocity and changes in wind direction may break the monolayer and thus special efforts are required for the maintenance of the film after such events. Presence and continuity of the film can be ascertained by putting a drop of an indicator oil like castor oil on the treated water surface. If the drop of the indicator oil maintains its shape, it shows the presence of the film.

6.2 Application in Powder Form

6.2.1 The suggested dose for application of WER in powder form is approximately 75 g/hectare of water surface per day. As the powder is supplied in lump form, it is required to be pulverised into a fine powder form by using a manual or mechanical pulveriser. The powder can be dispersed on water surface from boat by means of manually operated dusters.

6.2.2 For quickness and economy in application, two dusters may be fixed on either side of the boat. Speed of the boat should be regulated in such a way that minimum disturbances occur on the water surface, while completing the dusting as quickly as possible. Depending on the area of water spread, passes of the boat are suitably arranged while taking advantage of the wind direction.

6.2.3 Presence of the film on water surface may be ascertained as in the case of emulsion form. About 10 to 15 percent of the daily dose of WER may be kept reserved for use whenever the film is broken.

6.2.4 Depending upon local conditions, a method of combining the use of emulsion and powder forms is generally found optimal. During the night, WER solution may be applied using drips on floating rafts located suitably in the reservoir. During the day, WER powder can be sprayed for maintenance of continuous film, taking into account the wind direction.

6.3 Quality of Water

During the course of application of WER for evaporation control, the quality of water may be monitored and effects on the same shall be carefully studied.

6.4 Equipment

The equipment required for spreading WER and for assessing the saving in evaporation loss are detailed in Annex C.

6.5 Guidelines for Testing Film Pressure

The pressure that a monolayer builds on the treated surface of water can be indicated approximately by use of oils of known spreading pressures. The spreading pressure of various oils are given in Annex B. A small drop of any of these oils is applied over the monolayer, whose pressure is to be assessed. If the indicator oil drop spreads, it is evident that water surface carries a film at a pressure lower than spreading pressure of indicator oil. If the drop does not spread, it indicates that the film pressure is greater than the spreading pressure of the indicator oil. Oils of different spreading pressures in the working range should be kept ready at the site before field application of WER.

ANNEX A

(*Clause* 4.1.3)

RECOMMENDED TREE, SHRUB AND GRASS SPECIES FOR DIFFERENT REGIONS OF INDIA

Northern Region (Plains of Punjab, Haryana, Uttar Pradesh, Delhi and Parts of Gujarat and Madhya Pradesh)

Botanical Names	Vernacular Names	Habit
Acacia nilotica	babool	T
A Jacquemontii	bouli	ST
Albizia lebbeck	kala siris	T
Aroundo donax	baranal	S
Agave americana	grit kumari	S
Capparis decidua	kair	S
Dalbergia sissoo	shisham	T
Euphorbia royleana	thar	S
Impomoea crassicaulis	besharam	S
Jatrohpa curcas	ratan jyoti	S
Lawsonia inermis	mehandi	S
Parlinsonia aculeata	uilayati keekar	ST
Sasharum bengnalensis	munj	G
Syzygium cumini	jamun	T
Sesbania sesban	jayanti	S
Tecoms stans	sonnapatti	S
Tamarix aphylla	farash or jhau	T
Thevetia peruviana	kaner	S
Vitek negundo	nirgandi	S
Ziziphus nummularia	ber	S

Central Region (Parts of Gujarat, MP, Andhdra Pradesh and Maharashtra)

Botanical Names	Vernacular Names	Habit
Acacia nilotica	babool	T
A ctechu	khair	T
Agave sislana	grit kumari	S
Boswellia serrata	salai	T
Cassia siamea	siamea	T
Dalbergia latifolia	sitsal	T
Gliricida maculata	madre	ST
Hardwicxia binata	anjan	T
Jatropha curcas	ratan jyoti	S
Leucaena leucocephola	ipil-ipil	ST
Melia azadirachta	bakain	T
Pithecellobium dulcis	jangal jalebi	ST
Pongamia pinnata	karanj	T
Ricinus communis	arand	ST
Sesbania grandiflora	basna	ST

T = Tree, ST = Small Tree, S = Shrub, G = Grass

Source : Technical Bulletin (AGRIC) No. 22, ICAR, New Delhi (1969) by J.K. Ganguly and R.N. Kaul.

Southern Region (Tamil Nadu, Parts of Andhra Pradesh, Karnataka and Kerala)

Botanical Names	Vernacular Names
Acacia nilotica	babool
A auriculiformis	wattle
A decurrens	blackwattle
Agave sp.	grit kumari
Anacardium occidentale	kolamavu
Albizia lebbeck	magei
Bombusa sp.	mungli
Borassus flabellifer	panei
Casuarina equisitifolia	chauku
Erythrina spp.	mulu moduyu
Eucalyptus spp.	ecucalyptus
Gliricida maculata	—
Grevillea robusta	silveroak
Jatropha curscas	nepalam
Pueraria javanica	—
Sesbanta sesban	chittikatti
S bispinosa	jayanti
Telphrosia candida	lashtia

Eastern Region (West Bengal, Assam, Orissa and Bihar)

	Botanical Names	Vernacular Names
a)	*Inland areas*	
	Acacia catechu	khair
	Agave sislana	kantala
	Anacardium occidentale	kaju
	Artoarphus heterophyllus	kathal
	Arundo donax	gaba nal
	Bambusa sp.	bans
	Borassus flabellifer	tal
	Casuarina equisetifolia	janguli saru
	Cocos nucifera	narial
	Dalbergia sissoo	shisham
	Imperata cylindrica	ulu
	Lannea caromandelica	jhingal
	Musa paradisiaca	jela

Botanical Names	Vernacular Names
Syzygium cumini	jamun
Tephrosia candida	lashtia
Vitex negundo	nirgandi

b) *Coastal areas*

Botanical Names	Vernacular Names
Acacia acricuiformes	sonejhur
Anacardium occidentale	kaju
Borassus flabellifer	tar
Casuarina equisitifolia	janglisaru
Cocos nucifera	narial
Delonix elata	gulmohar
Erythrina indica	polita mandas
Buphurbia tirucalli	sehund
Bicus spp	gad gubar
Indiqofera aspalathoides	sivanimba
Ipomoea biloba	natilata
Pongamia pinnata	karanj
Prosopis juliflora	vilayati babool
Inifex littorcus	rawn moonch
Tamarix aphylla	farash
Thespsia populnea	paraspipa

Arid Region (Western Rajasthan, Part of Andhra Pradesh and Karnataka)

Botanical Names	Vernacular Names
Acacia nilotica	babool
A leucophloea	reonja
A planifrons	godugh thumba
A Senegal	kummet
A Tortilis	israelibabool
Balanites aegyptiaca	hingot
Calligonum polygonoides	phog
Capparis decidua	kair
Clerodendrum phlomoides	arni
Saccharum munja'	munj
Eucalyptus camaldulensis	eucalyptus
Euphoribia caducifolia	thor
Lasiurus sindicus'	sewan
Panicum turgidum	murat
Tamarix aphylla	farash
Zizyphus nummularia	jharber

ANNEX B

(*Clauses* 5.2.1 *and* 6.5)

SURFACE PRESSURE OF INDICATOR OILS AT 21°C

Sl No.	*Indicator Oils*	*Surface Pressure Developed at 21°C (dynes/cm²)*
1.	Shell ensis fluid 256	40.0
2.	Undocylic acid	34.5
3.	Hexadecyl acetate	34.4
4.	Oloic acid	30.0
5.	Octadecyl acetate	24.0
6.	Shell vitrea oil 21	24.0
7.	Triolein	22.0
8.	Lauric acid	21.0
9.	Castor oil	17.0
10.	Ethyl pholometite	16.5
11.	Shell vitrea oil 13	16.0
12.	Shell H.S.D.	13.0
13.	Triorozyl phosphate	10.0
14.	Myrystic acid	11.0
15.	Palmitic acid	8.5
16.	Carbon disulphide	2.3
17.	Steanic acid	1.5

ANNEX C

(*Clause* 6.4)

EQUIPMENT REQUIRED FOR APPLICATION OF CHEMICAL WERs AND FOR ASSESSMENT OF EVAPORATION LOSS

Sl No.	*Equipment*	*Purpose*
1.	Motorized boat	Spraying WER
2.	Dusters	Dusting WER
3.	Pulverizers	Pulverizing WER
4.	Floating raft and drums	Dripping WER
5.	Anchors/chains	Anchoring of rafts
6.	Pan evaporimeter (land type) (IS 5973) — 2 Numbers (one in chemically treated condition and the other in untreated condition	Measurement of evaporation loss from treated water surface and from untreated surface
7.	Anemometer — 1 Number	Measurement of wind velocity
8.	Windvane (IS 5799) — 1 Number	Observation of wind direction
9.	Thermometer screen (IS 5948) — 1 Number	Fixing and protecting thermometer
10.	Dry and wet bulb — 1 set thermometer with conversion charts	Measurement of humidity
11.	General meteorological Thermometer (IS 5681) — 1 set	Measurement of minimum and maximum temperature during a day
12.	(IS 5235) — 1 Number	Measurement of rainfall
13.	Sunshine recorder (IS 7243) — 1 Number	Measurement of total sunshine hours during a day
14.	Aneroid Barometer — 1 Number (IS 5793)	Measurement of atmospheric pressure
15.	Mercury barometer (IS 5798)	Measurement of atmospheric pressure

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards Monthly Additions'.

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